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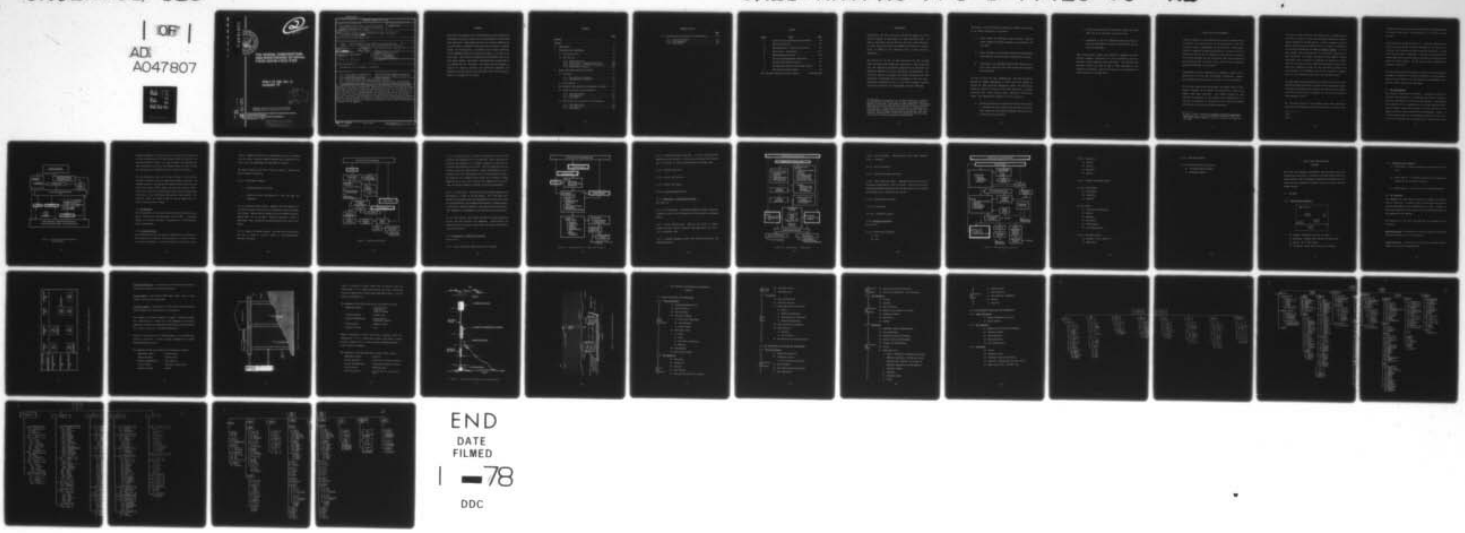

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THE DESIGN, CONSTRUCTION AND MAINTENANCE OF NAVAL FIXED OCEAN FACILITIES

FPO-1-77 (20, Vol. 1)
AUGUST 77

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Vol. 5 Fixed Ocean Facilities Bottom Mounted Surface Structures Work Breakdown Structure Charts from Volumes 2, 3, 4, & 5 are inserted in back of this volume.

13. Abstract: Ocean Facilities Engineering is the application of ocean engineering knowledge to the design, construction, and maintenance of naval Fixed Ocean Facilities. Fixed Ocean Facilities are structures supported by the ocean floor or attached to the ocean floor by means of a mooring system. The structure may: (1) penetrate the air-water interface, (2) be suspended between the surface and bottom, or (3) rest on the ocean floor. The scientific disciplines and technology areas of the three phases (design, construction, and maintenance) of Ocean Facilities Engineering are introduced. The ocean facility engineer is required to integrate practical and operational knowledge with advanced scientific concepts and technology to meet current requirements and to prepare for the future.

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ABSTRACT

Ocean Facilities Engineering is the application of ocean engineering knowledge to the design, construction, and maintenance of naval Fixed Ocean Facilities. Fixed Ocean Facilities are structures supported by the ocean floor or attached to the ocean floor by means of a mooring system. The structure may: (1) penetrate the air-water interface, (2) be suspended between the surface and bottom, or (3) rest on the ocean floor. The scientific disciplines and technology areas of the three phases (design, construction, and maintenance) of Ocean Facilities Engineering are introduced. The ocean facility engineer is required to integrate practical and operational knowledge with advanced scientific concepts and technology to meet current requirements and to prepare for the future.

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FIGURES

1. INTRODUCTION

Historically, the Naval Facilities Engineering Command has given technical support to shore-based U.S. naval operating forces. In 1968, by instruction from the Office of the Chief of Naval Material, the Naval Facilities Engineering Command was assigned the responsibility of supporting naval operating forces in ocean facilities engineering.

This decision by the Navy to take construction out into the deep ocean* was based on the recognition of two factors. One, the Navy saw that a new engineering discipline, recognized by the educational and industrial communities as ocean engineering, was developing. Two, the Navy's 200-year involvement with defense technology made them interested in encouraging the full development of this new, multidisciplinary engineering field, a field which combines classical engineering disciplines with oceanography and ocean technology.

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*At the beginning of World War II, the Navy formed several construction battalions to do the work that civilian contractors could not perform in a war zone. The Navymen in these battalions -- the Seabees, whose name was derived from the first initials of the term construction battalion -- gained their first experience in underwater construction when they built advance bases in the Pacific. Their work consisted mainly of demolition and salvage projects and coral reef blasting. When World War II ended, the underwater skill continued to be used on bridge and waterfront structure work.

Specifically, the Naval Facilities Engineering Command was chartered as the Command responsible for providing:

- Fixed surface and subsurface ocean structures, floating cranes, amphibious pontoon equipment, fleet moorings, and lift docks.

- Tools, equipment, and techniques required for construction and maintenance of fixed surface and subsurface structures.

- Architectural and engineering design and construction of naval shore facilities and fixed surface and subsurface ocean structures.

In order to carry out this responsibility, the Naval Facilities Engineering Command implemented an Ocean Facilities Program to develop the ocean facilities engineering, design, and construction capability required to provide fixed ocean facilities at minimum life-cycle cost, using military and/or contractual construction forces. The organizational components of this program are:

a. The Ocean Engineering and Construction Project Office (FPO-1), Chesapeake Division, Naval Facilities Engineering Command, tasked with the technical management and execution of the Ocean Facilities Program.

b. Two Naval Construction Force Underwater Construction Teams (UCTs) who do the underwater construction work.

c. A department at the Civil Engineering Laboratory that provides the development of necessary ocean facility and construction technology.

These organizational elements were combined to implement the Naval Material Command's instruction that ocean engineering support be provided to naval operating forces (the Fleet). This required that extensive research and study be made in ocean engineering, a new engineering discipline, untried and untested in its application to naval operations in the deep ocean.

2. OCEAN FACILITIES ENGINEERING

"Ocean engineering is a new multidiscipline branch of technology that is based on the classical areas of engineering and on the newer scientific fields of oceanography and related fields. A new breed of engineer is beginning to emerge who typically is trained in one of the classical fields but who has expanded his interests and the scope of his working knowledge into the disciplines that have traditionally been associated with the ocean, such as marine biology, underwater geology and chemistry of the oceans."[1]

Oceanography and ocean engineering are recognized fields, and the application of this new base of knowledge is broadening. However, many fundamental questions about the oceans are still unanswered.

For the naval ocean facilities engineer, the present state of knowledge is adequate for the design and construction of some of the simpler fixed ocean facilities. For complex systems with long lifetimes and emplaced at great depths, much advancement will be required to understand the interactions of the ocean's environment with materials, structures, and ocean engineering.

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[1] By John J. Myers in foreword of Handbook of Ocean and Underwater Engineering, Myers, Holm and McAllister, McGraw Hill 1969, Copyright North American Rockwell, Library of Congress Catalogue Card #67-27280.

"The ocean is often believed by the engineer who is inexperienced in its ways to be always a violent, hostile medium needing major technological advances for its exploitation. In fact, although not a benign medium, particularly during storms, much of the ocean is conquerable with existing engineering knowledge if properly applied -- but the ocean demands good engineering and is particularly unforgiving of poor engineering. For example, pressures at ocean depths, although exceedingly high by atmospheric standards, are handled by existing materials; corrosion, while an important environmental result, can be kept within acceptable bounds for many engineering purposes with known materials and techniques; and fouling, although a nuisance, does not limit underwater activities in any substantial way."[2]

The ocean facilities engineer must work closely with the technical and operational people experienced in actual work-at-sea problems (UCTs). "Such experienced people will frequently see possibilities to cooperate with the ocean and its environment in a way that will ease the ocean engineers' task."[3]

The following sections of this document define more specifically Ocean Facilities Engineering and Naval fixed ocean facilities. Engi-

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[2] Ibid.

[3] Ibid.

neering functions and interacting technology areas encompassed during the design, construction, and maintenance of a facility are also outlined.

Ocean Facilities Engineering (OFE) is a systematic application of existing engineering and scientific knowledge to the design, construction, and maintenance of naval fixed ocean facilities. A fixed ocean facility (FOF) is basically a structure with related utility systems supported by the ocean floor or attached to the ocean floor by means of a mooring system. The FOF types and their components are discussed in section 3.

The three major phases of OFE (design, construction, and maintenance) encompass a multitude of scientific disciplines and technologies. Areas of prime concern for all OFE functions are performance, reliability, safety, economy, and timeliness.

2.1 OFE RELATIONSHIPS

OFE requires a broad base of knowledge -- engineering, scientific, practical, and operational -- to determine the technical feasibility and cost effectiveness of the various FOF concepts. The knowledge base, combined with the capabilities of the Naval Facilities Engineering Command, enable the OFE group to provide facilities which support the Navy's mission effectively and economically. Figure 1 is a block diagram showing the relationship of OFE and its major functions to the knowledge base and capabilities of the Naval Facilities

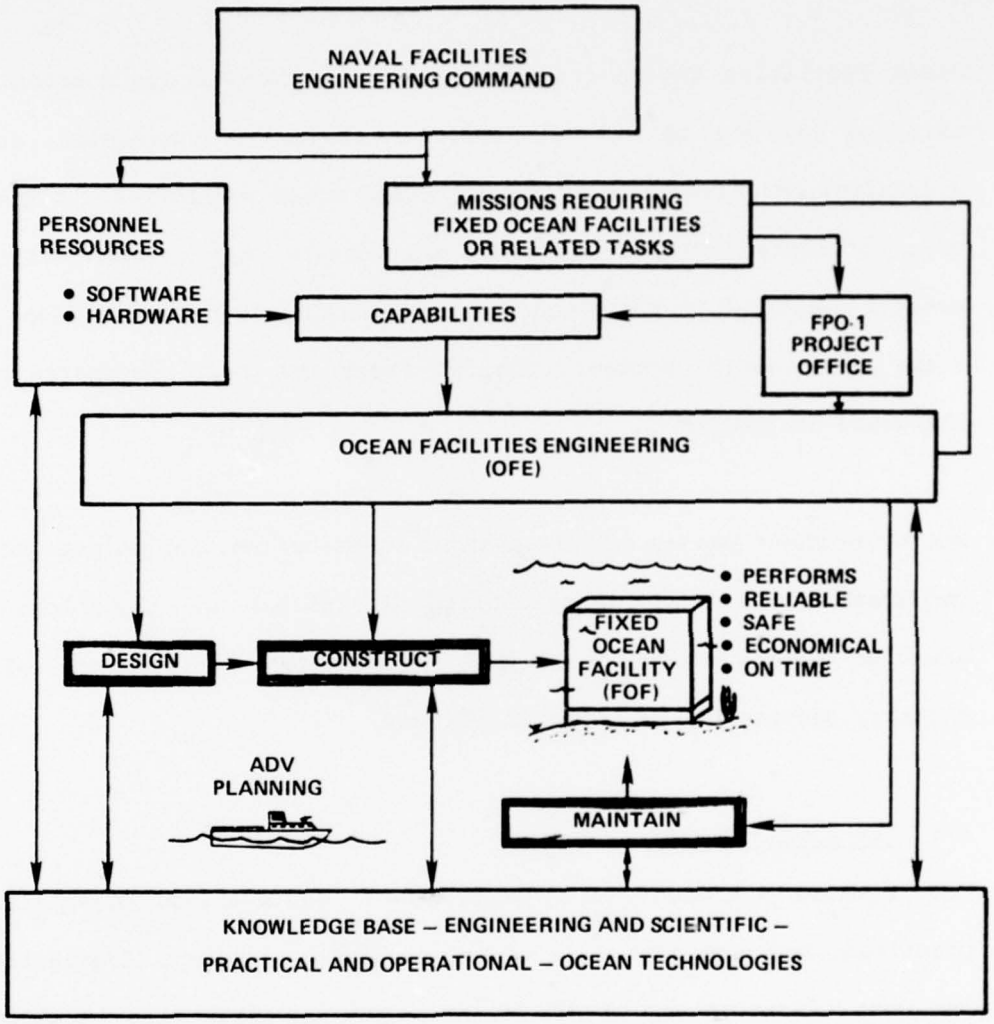


Figure 1. Ocean Facilities Engineering Relationships

Engineering Command. Note that there is a two-way flow of information from the knowledge base to the OFE, Design, Construct, Maintain, and Personnel-Resources blocks. In order to expand the knowledge, advance technically, and solve the problems within the field of OFE, this two-way flow of information must be a continuous process.

The OFE methodology starts at the top of Figure 1 with the Navy providing the mission and the supporting personnel, software, and hardware resources. The missions go through the Ocean Engineering and Construction Project Office (FPO-1) for planning, priority evaluations, and routing to the proper phase of OFE. With the capabilities and mission in hand, OFE performs the specific tasks required. The tasks may involve all phases of OFE or they may apply only to a specific function within a phase.

2.2 OFE FUNCTIONS

OFE is responsible for the various technical functions related to the design, construction, and maintenance of naval FOF. A breakdown summary of the major functions is presented here in chronological order of performance.

2.2.1 Design Functions

The design phase of OFE is primarily responsible for selecting the most effective and efficient site and facility, in order to satisfy the mission requirements. To insure minimum life cycle costs of the

facility, maximum reliability and maintainability must be designed into the system. Thorough trade-off analyses must be performed so as not to sacrifice performance and timeliness for economy.

The design process of the FOF, as shown in Figure 2, includes the basic functions listed here.

2.2.1.1 Requirements Analysis.

a. Establish design life of FOF.

b. Establish mission requirements for site, FOF type, and components.

2.2.1.2 Conceptual Design Studies. Depending upon the complexity of the mission, several iterations may be required to create the conceptual designs. State-of-the-art capability versus research and development needs will be reviewed. Trade-off analyses in areas of performance, cost, reliability and maintainability will then be conducted.

2.2.1.3 Selection of Design Concept. The selection of the FOF type and site is based on criteria related to cost-effectiveness, schedule, and safety.

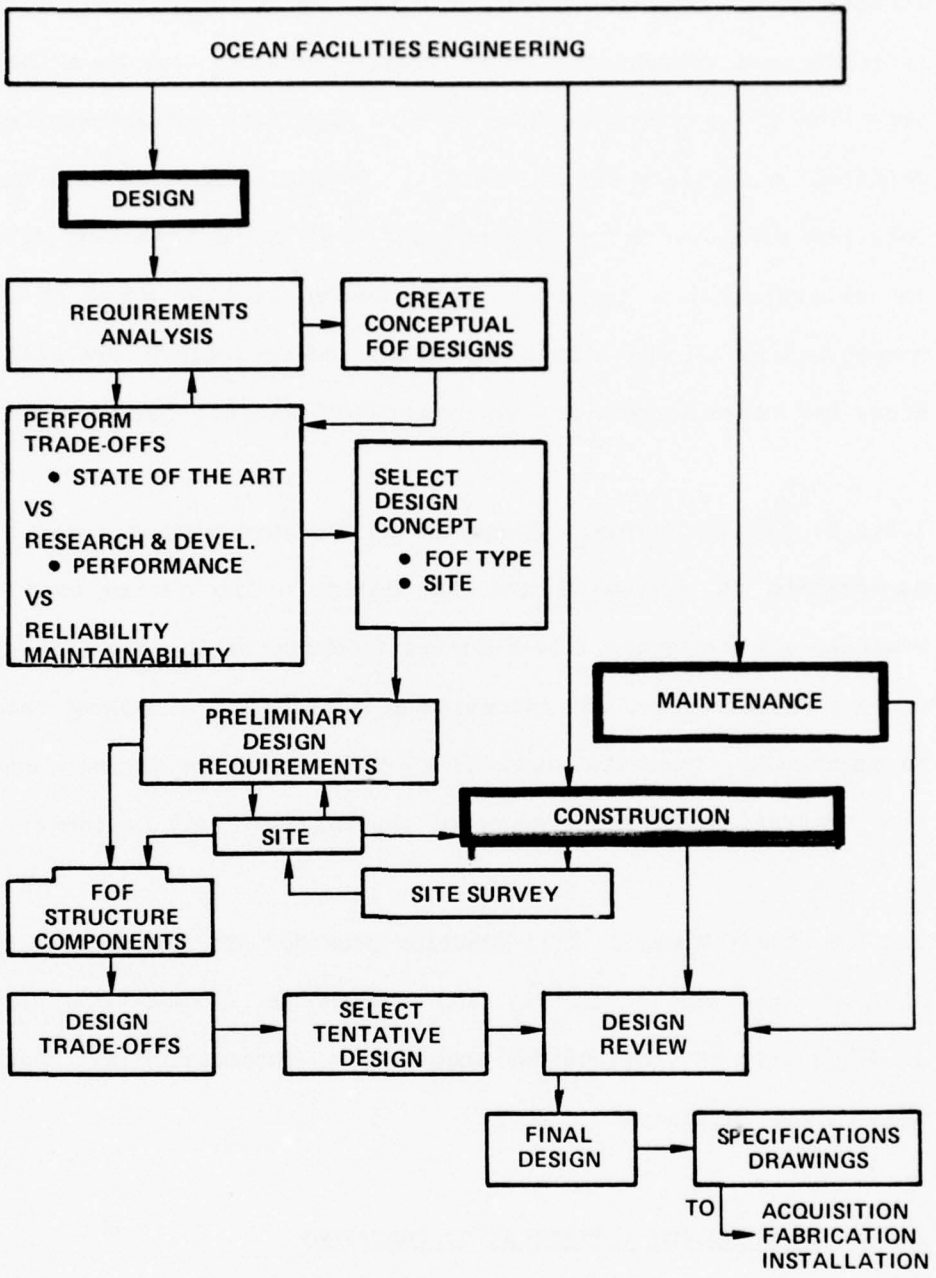


Figure 2. OFE Design Functions

2.2.1.4 Preliminary Design. Specific requirements for the site, FOF structure, and components will be established. Before designing the structure and components, it is usually necessary to have the construction group conduct a site survey. The site characteristics are critical to facility design factors. Design trade-offs will be at a detailed level, with performance and cost being important factors. The selection of a tentative final design will be based on design compatibility of the site's structure and components and will consider the factors necessary to satisfy the mission requirements.

2.2.1.5 Design Review. Construction and maintenance experts will participate in review of the FOF design. The review board will evaluate the projected life-cycle performance of the facility, point out any deficiencies, and recommend effectiveness or economy changes. In particular, potential hazards to safe operation during construction, operation, or maintenance of the facility will be identified.

2.2.1.6 Final Design. This function provides for system integration of the site, FOF structure, and components. Specifications and drawings will be provided for acquisition, fabrication and installation of the facility.

2.2.2 Construction - Preparation Functions

See Figure 3a.

2.2.2.1 Review FOF Plans, Specifications, and Drawings.

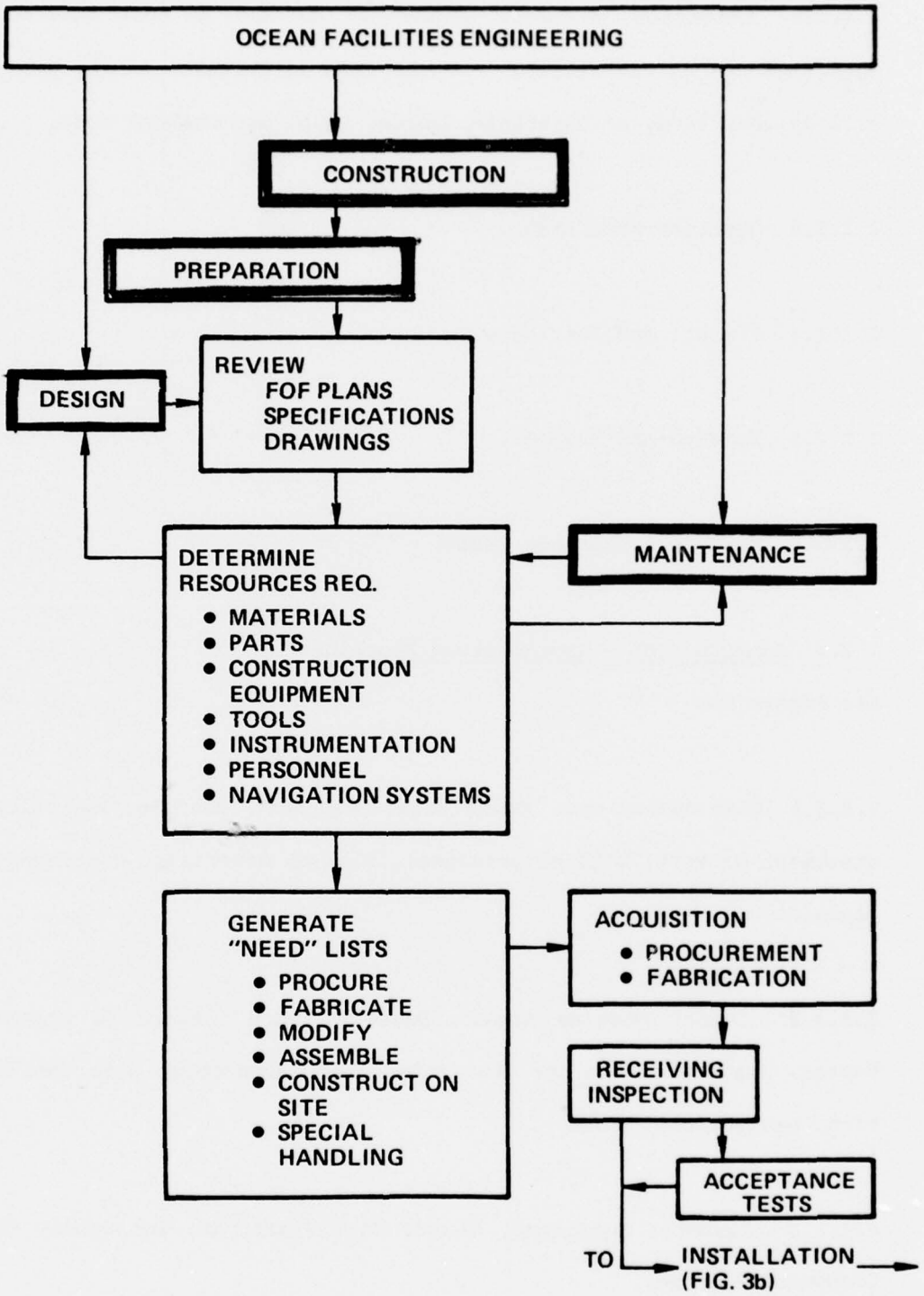


Figure 3a. OFE Construction - Preparation Functions

2.2.2.2 Determine Resources Required. It may be that materials specified are not available, in which case maintenance and/or design will be consulted, an alternate decided upon, and changes made.

2.2.2.3 Generate Need Lists.

2.2.2.4 Procure and Fabricate.

2.2.2.5 Receive and Inspect.

2.2.2.6 Perform Acceptance Tests.

2.2.3 Construction - Installation Functions

See Figure 3b.

2.2.3.1 Plan Operations. Operational sequence, schedule, logistics, statement of work, bill of personnel, bill of materials, contingency plans.

2.2.3.2 Select Staging Area. Based on such factors as channel depths, sea state, shelter available, land approaches, port facilities, navigational aids.

2.2.3.3 Assemble Equipment, Ships, Work Platforms, Personnel, FOF Components/System.

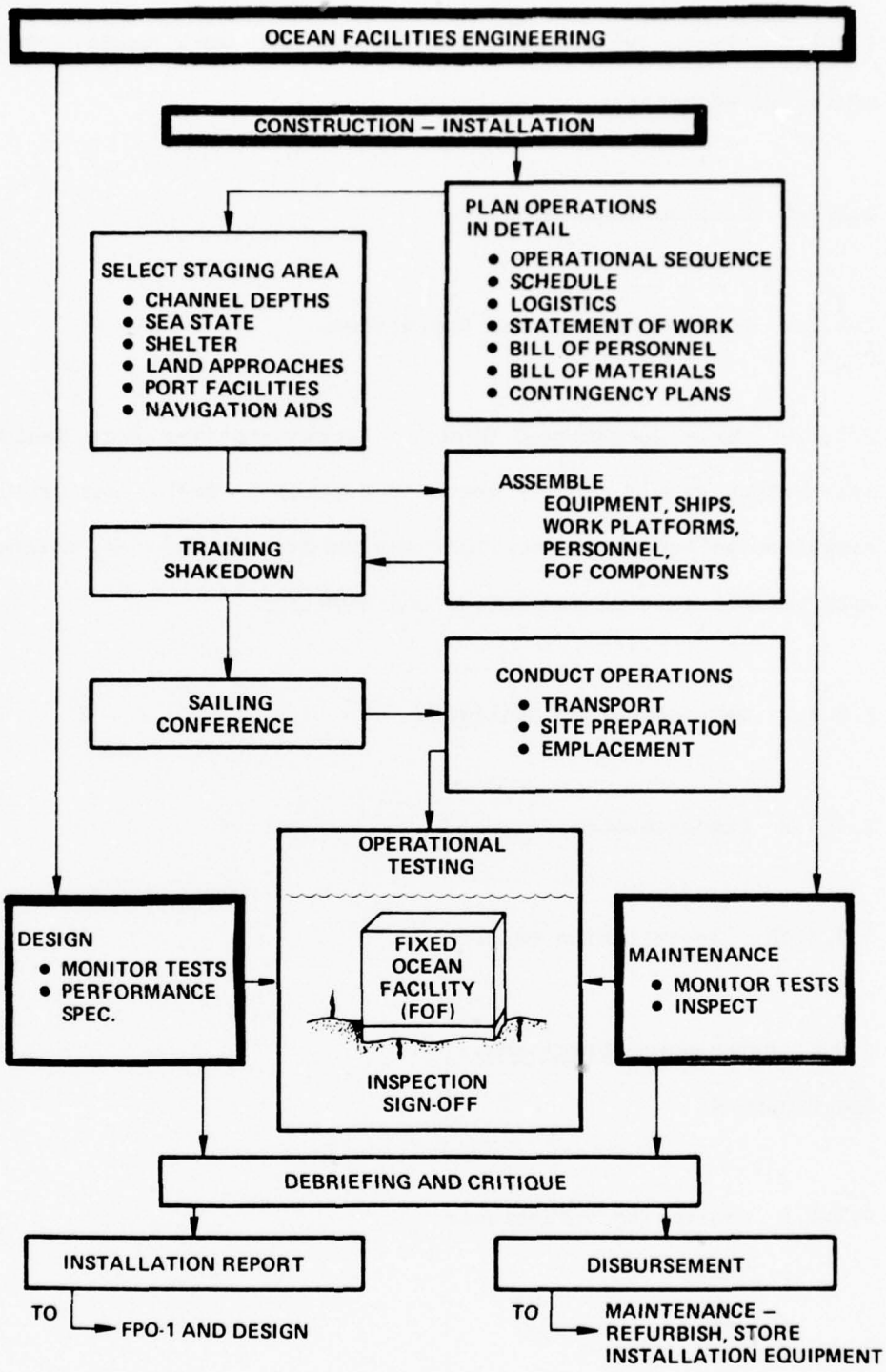


Figure 3b. Construction - Installation

2.2.3.4 Train Personnel. Assign specific work tasks, shakedown cruise if necessary.

2.2.3.5 Sailing Conference.

2.2.3.6 Perform Emplacement Operations.

2.2.3.7 Make Operational Tests. Representatives from design and maintenance should monitor tests if possible. Design has previously submitted performance specifications and test procedures; maintenance will perform initial inspection and sign off.

2.2.3.8 Debriefing and Critique.

2.2.3.9 Disbursement.

2.2.3.10. Installation Report.

2.2.4 Maintenance Functions.

See Figure 4.

2.2.4.1 Monitoring Performance.

(1) FOF

(2) Site

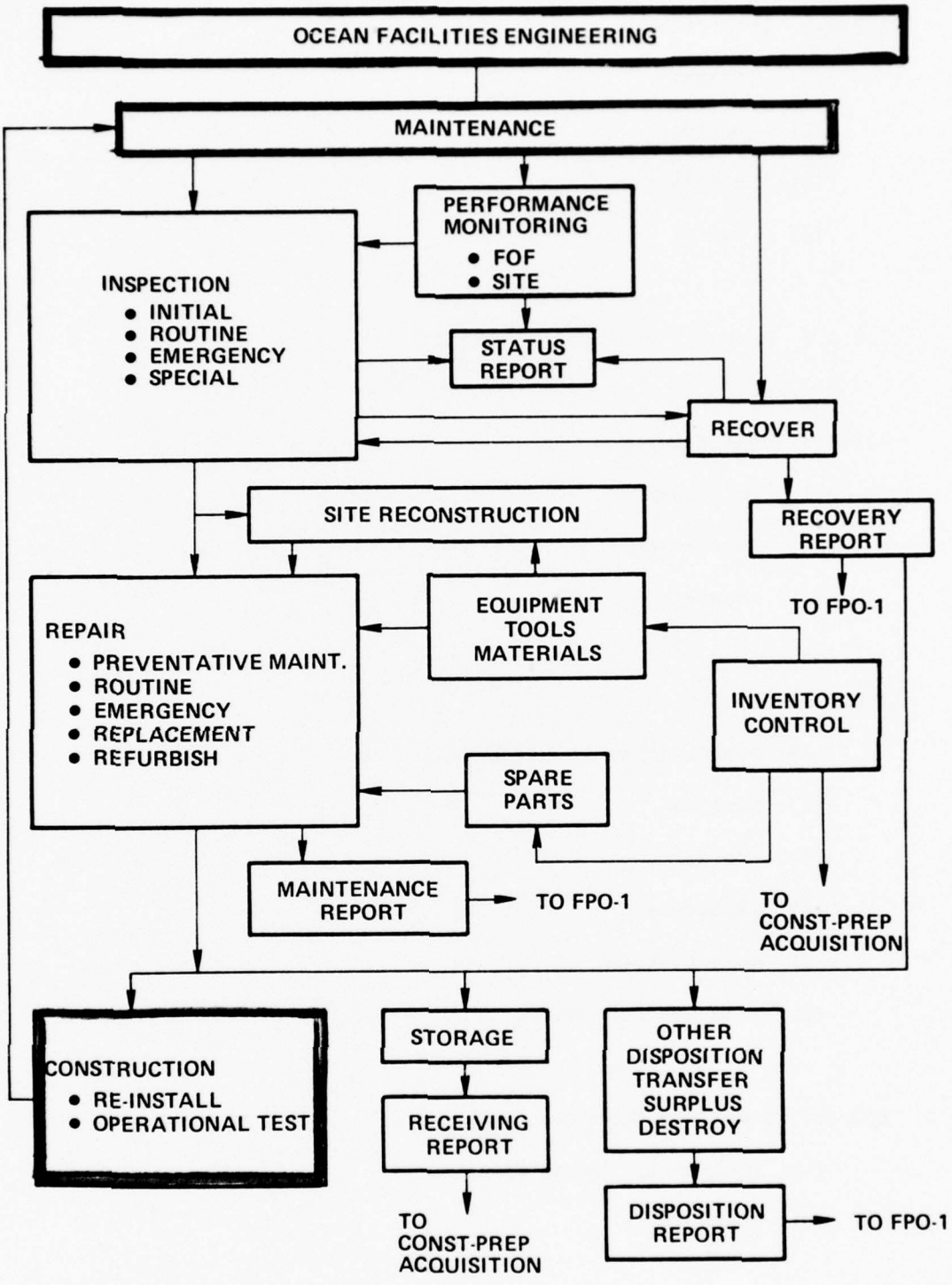


Figure 4. OFE Maintenance Functions

2.2.4.2 Inspection.

(1) Initial

(2) Routine

(3) Emergency

(4) Special

2.2.4.3 Recovery and Special Report.

2.2.4.4 Status Report.

(1) Performance

(2) Inspection

(3) Recovery

2.2.4.5 Repair.

(1) Preventative Maintenance

(2) Routine

(3) Emergency

(4) Replacement

(5) Refurbishment

(6) Site Reconstruction

2.2.4.6 Inventory Control.

(1) Equipment, Tools, Materials

(2) Spare Parts

2.2.4.7 Maintenance Report.

2.2.4.8 Storage and Other Disposition.

(1) In-storage Receiving Report

(2) Disposition Report

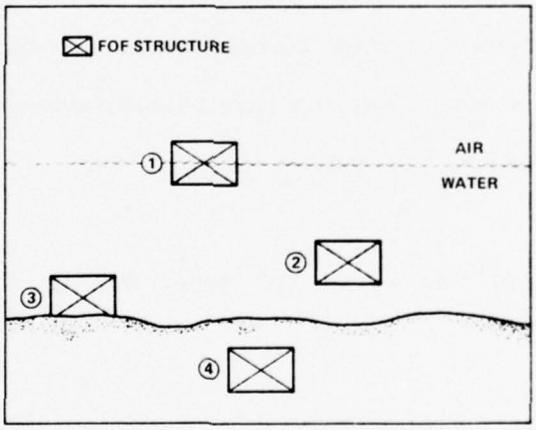
3. NAVAL FIXED OCEAN FACILITIES

(OUTLINE)

Naval FOFs are underwater installations and structures either supported by the ocean floor or attached to the ocean floor by means of a mooring system. They are designed, constructed, and maintained by the Naval Facilities Engineering Command to perform the Navy's national defense mission.

3.1 FOF TYPES

3.1.1 FOF Structure Categories



(1) Surface - Penetrates air-water interface.

(2) Subsurface - Between water surface and ocean floor.

(3) Bottom - On the ocean floor.

(4) Sub-Bottom - Those which penetrate the seafloor.

3.1.2 FOF Emplacement Categories

(1) Bottom Moored - Buoyant suspension systems anchored to the floor.

(2) Bottom Resting - In contact with bottom but without any foundation, may or may not be moored.

(3) Bottom Mounted - Pile, mat, rock or concrete foundation.

3.2 FOF COMPONENTS

The components of fixed ocean facilities are related to the basic types of facilities. In general, there are seven basic FOF types of structure/emplacement system combinations, as shown in Figure 5. These basic types may or may not have utility systems associated with them depending on the payload.

The components of the basic FOF types may be classified as the following:

Emplacement System - that portion of a FOF which supports the primary structure and holds it in a fixed position;

Primary Structure - that portion of a FOF which provides physical support to the payload accommodations;

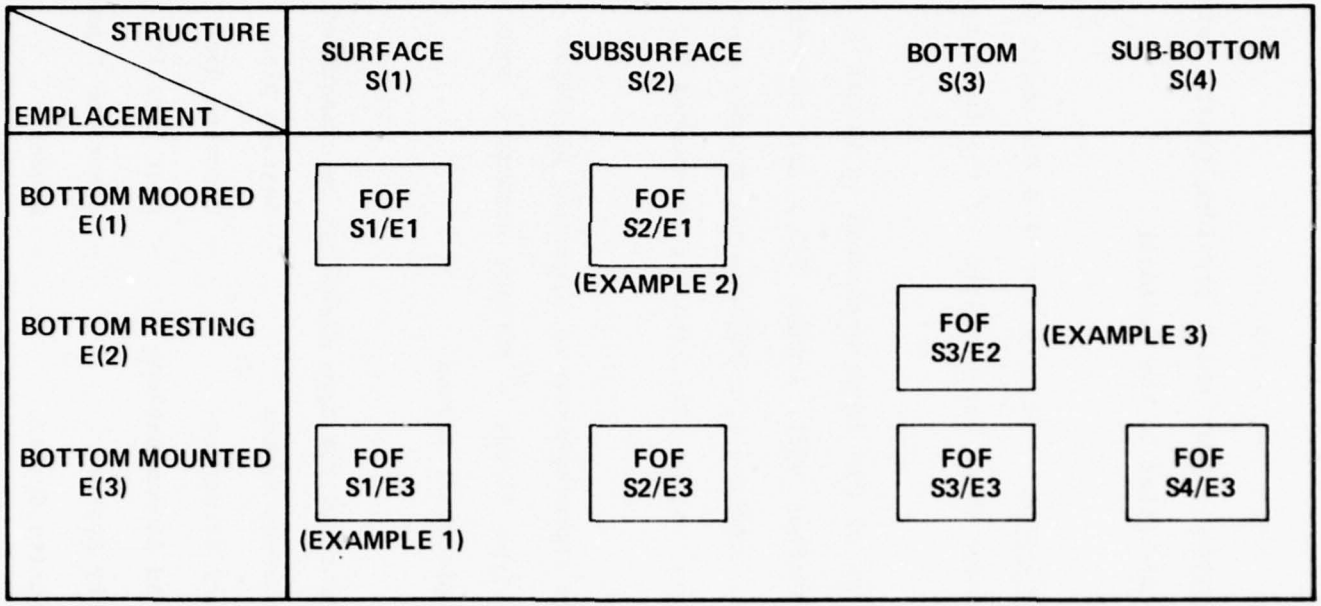


Figure 5. FOF Structure/Emplacement Combinations

Payload Accommodations - that portion of a FOF which encloses and/or attaches the payload to the primary structure;

Utility System - that which provides power, water, fuel or waste disposal facilities to the payload;

Protective System - that portion of a FOF which provides protection against damage to or deterioration of the facility.

The examples of FOF types presented in Figure 5 illustrate surface S(1), subsurface S(2), bottom S(3), and subbottom S(4) structure categories, combined with emplacement systems that are bottom moored E(1), bottom resting E(2), and bottom mounted E(3).

Figure 6 is representative of a mooring platform. It is a fixed ocean facility, type S1/E3, a surface structure combined with a bottom mounted emplacement system.

The components of FOF type S1/E3 may be classified as follows:

Emplacement System	- Bearing piles
Primary Structure	- Concrete deck
Payload Accommodations	- Deck facility
Utility System	- Generator & power cable
Protective System	- Fender

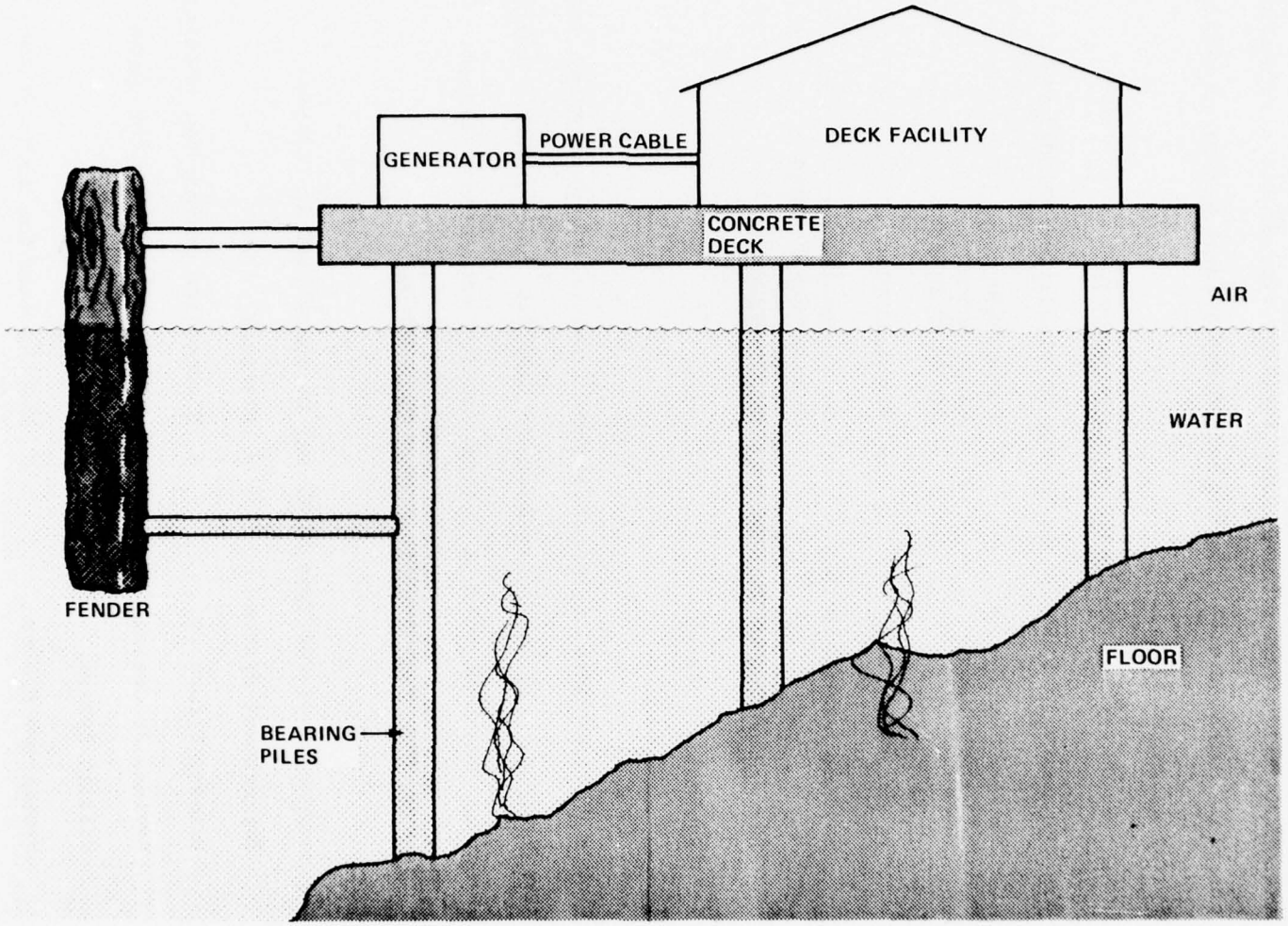


Figure 6. FOF Type S1/E3 Mooring Platform

Figure 7 represents a sensor system from an acoustic array test installation. It is a fixed ocean facility type S2/E1, a subsurface structure combined with a bottom moored emplacement system. A utility system is attached to it.

The components of FOF Type S2/E1 may be classified as follows:

Emplacement System	-	Subsurface buoy Clump anchor Acoustic release
Primary Structure	-	Braided nylon
Payload Accommodations	-	Sensor housing Transponder housing
Utility System	-	Submarine cable
Protective System	-	Paint

Figure 8 represents a sensor system from an acoustic array test installation. It is a fixed ocean facility type S3/E2, a bottom structure combined with a bottom resting emplacement system. A utility system is attached.

The components of FOF Type S3/E2 may be classified as follows:

Emplacement System	-	Platform
Primary Structure	-	Electronics cylindrical housing
Payload Accommodations	-	Cylindrical housing for sensor
Utility System	-	Submarine cable
Protective System	-	Rip rap mats for scour protection

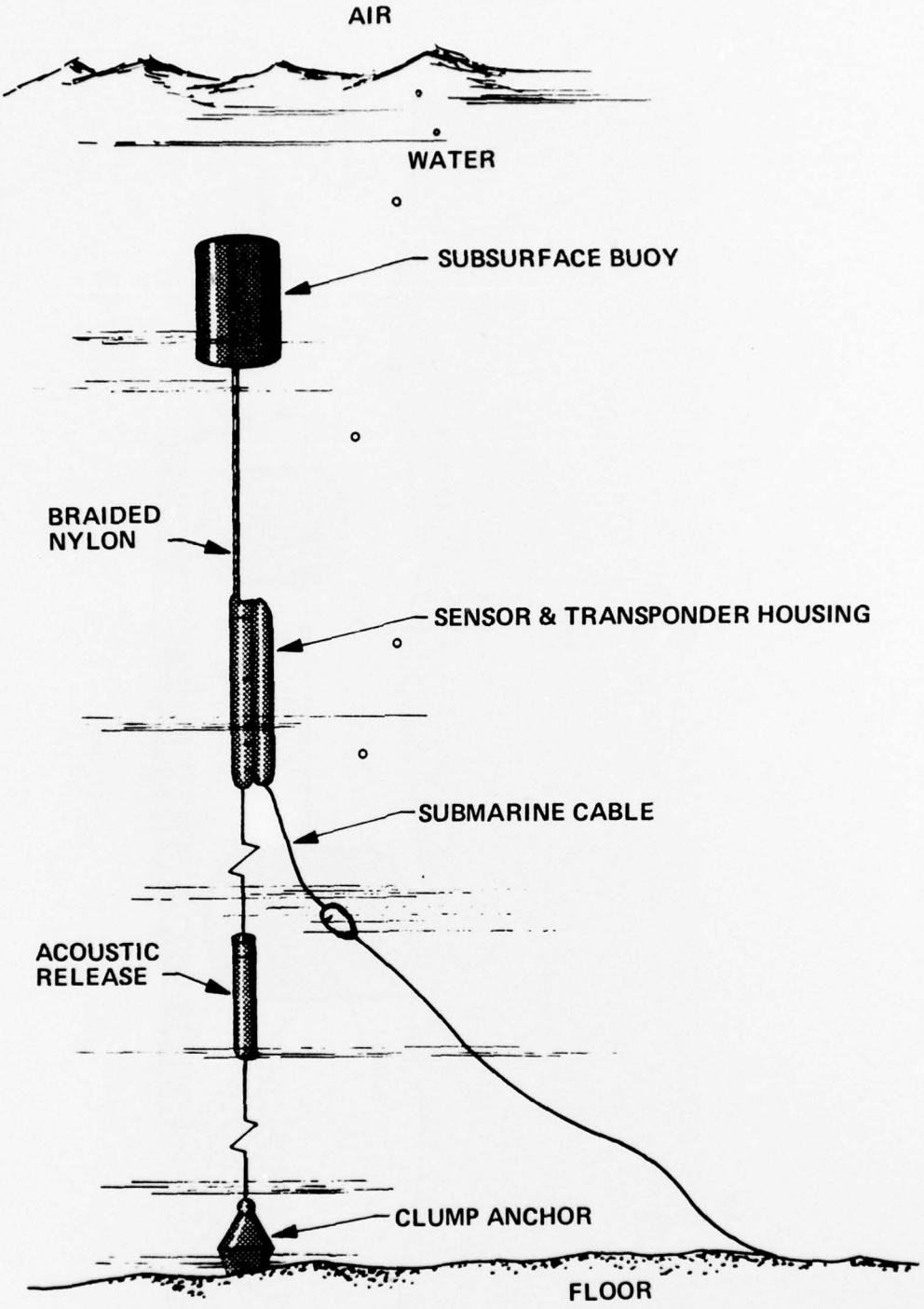


Figure 7. FOF Type S2/El Acoustic Array Sensor System

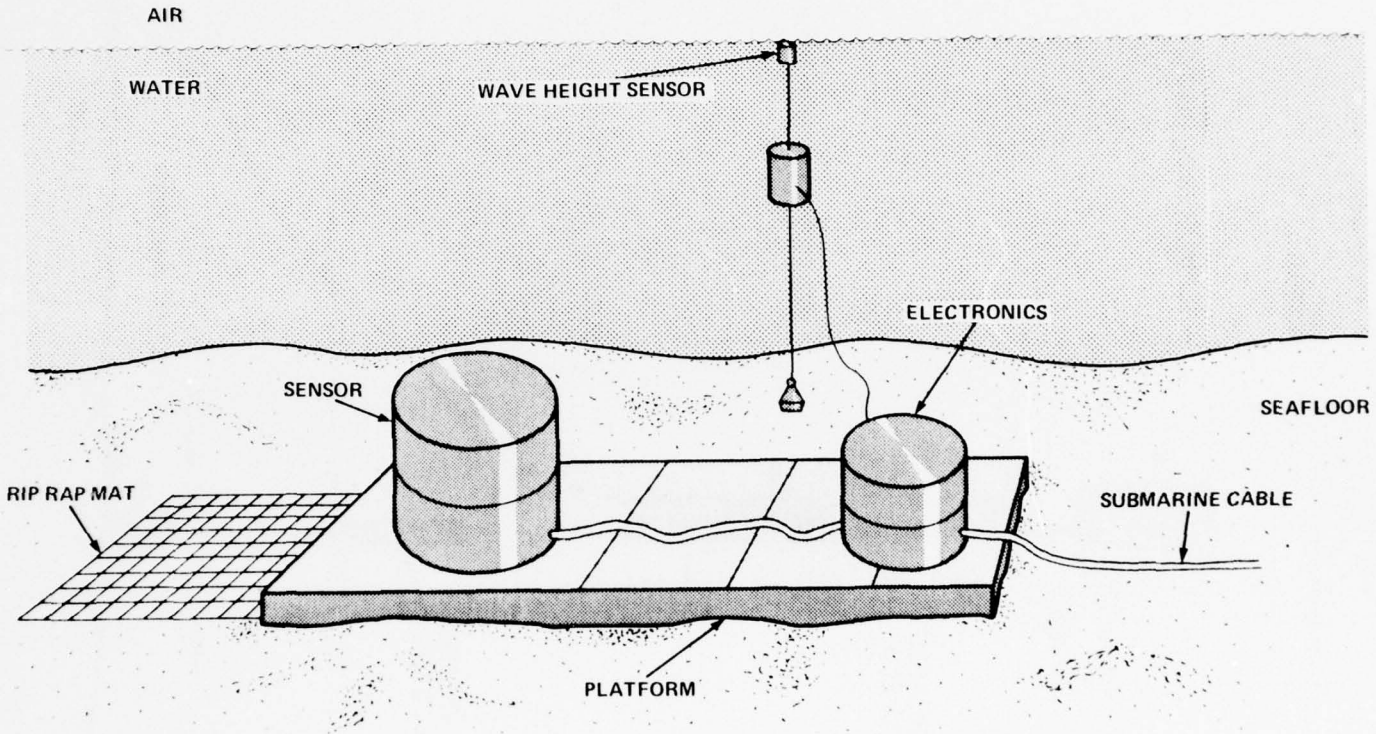


Figure 8. FOF Type S3/E2 Sensor System

4. OFE SCIENTIFIC DISCIPLINES AND TECHNOLOGIES

(LISTING)

4.1 DESIGN DISCIPLINES AND TECHNOLOGIES

4.1.1 Ocean Environment

Design Ocean Environment

- (1) Oceanography/Meteorology
- (2) Ocean Chemistry
- (3) Marine Biology
- (4) Underwater Geology
  - a) Ocean Floor Topography
  - b) Soil Mechanics
  - c) Seismic Zones
- (5) Underwater Fields
  - a) Sound
  - b) Light
  - c) Radio Wave Transmission
  - d) Magnetic
- (6) Hydrodynamics
- (7) Wind and Wave Loads

4.1.2 FOF Components

Design FOF Components

- (1) Structures
- (2) Foundations
- (3) Moorings
- (4) Power Sources
- (5) Materials and Protective Coatings

Design FOF Components

(6) Underwater Cables

(7) Instrumentation

4.1.3 FOF System

Design FOF System

(1) Test and Evaluation

(2) Resources and Cost

(3) Ocean Operations and Logistics

a) Safety

b) Anchoring Techniques

c) Lowering/Lifting Techniques

d) Handling/Transporting

(4) Ocean Construction Equipment

(5) Specifications

a) Drawings

b) Parts Control

(6) Documentation (Information System)

4.2 OFE CONSTRUCTION DISCIPLINES AND TECHNOLOGIES

4.2.1 Ocean Environment

Construction Ocean Environment

(1) Geophysical Surveying

(2) Underwater Geology

a) Soil bearing load capacity

(3) Marine Hazards

(4) Soil Sampling and Stabilization

(5) Rock Exploration

Construction Ocean Environment

(6) Wave Tide and Storm Forecasting

(7) Survey Instrumentation - Data Processing

4.2.2 FOF Components

Construction FOF Components

(1) Pilings

(2) Moorings

(3) Marine Concrete

(4) Materials and Protective Coatings

(5) Underwater Cables

(6) Fabrication

(7) Anchors

4.2.3 FOF System

Construction FOF System

(1) Underwater Tools and Manipulators

(2) Drilling Systems

(3) Underwater Cutting and Welding

(4) Rigging, Tackle and Techniques

(5) Winches and Deck Machinery

(6) Diving

(7) Ocean Operations

a) Safety - Underwater, shipboard, small boat, offshore structures, firefighting, weight handling gear, handling and stowage of dangerous substances, electro magnetic radiation hazards

b) Anchoring

c) Lowering/Lifting

d) Towing

Construction FOF System

e) Communications

f) Ship Chartering

g) Ship Handling & Seamanship

h) Staging

i) Logistics

4.3 OFE MAINTENANCE DISCIPLINES AND TECHNOLOGIES

4.3.1 Ocean Environment

(1) Meteorology/Weather Forecasts

(2) Marine Hazards

4.3.2 FOF Components

(1) Mechanical and Electrical Equipment

(2) Underwater Cables

(3) Marine Concrete

(4) Repair Materials

(5) Soil Stabilization

4.3.3 FOF System

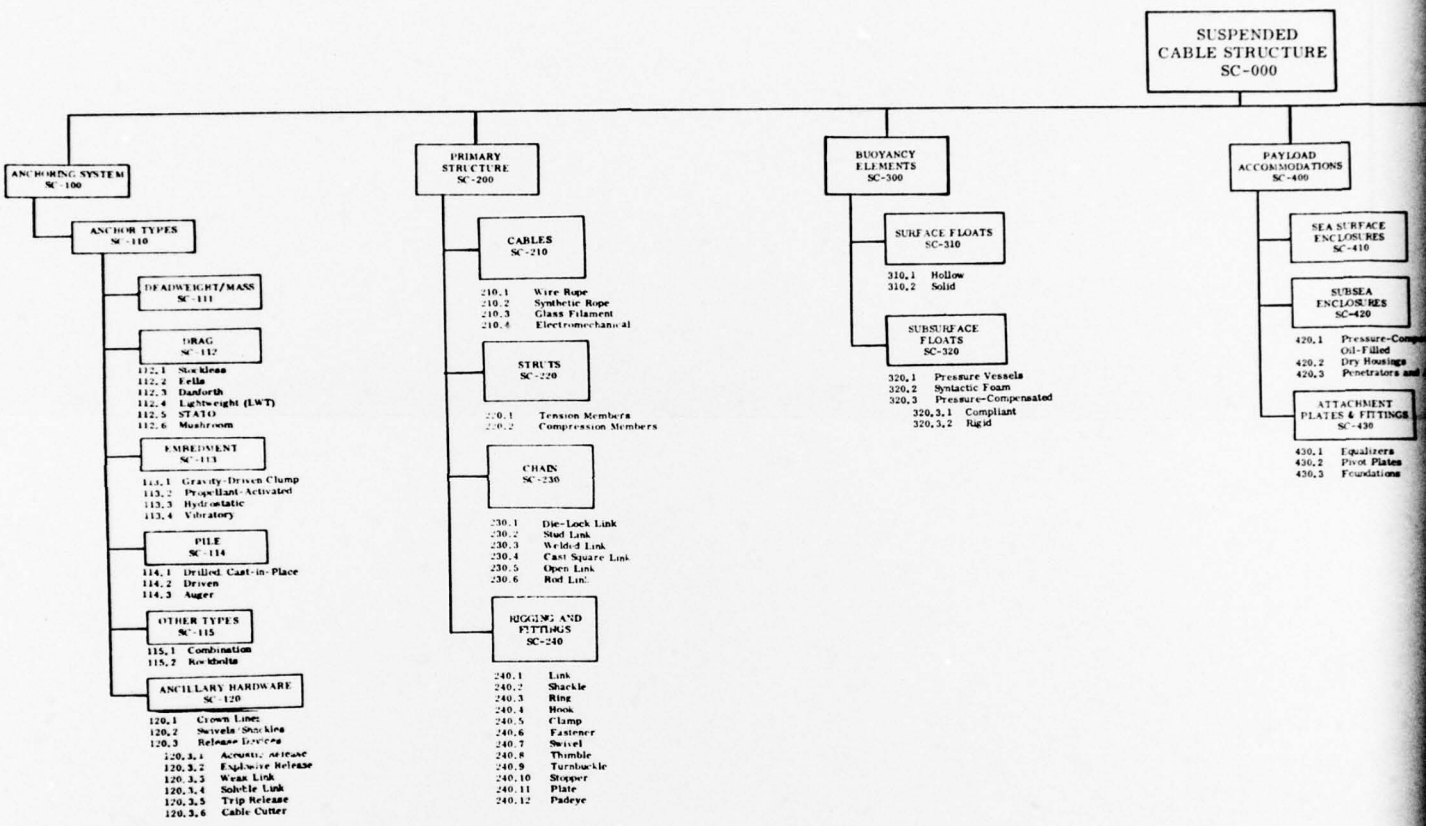
(1) Diving

(2) Underwater Tools

(3) Underwater Cutting and Welding

(4) Logistics - Maintenance and Repair Crews

(5) Repair Facilities - Drydocks, etc.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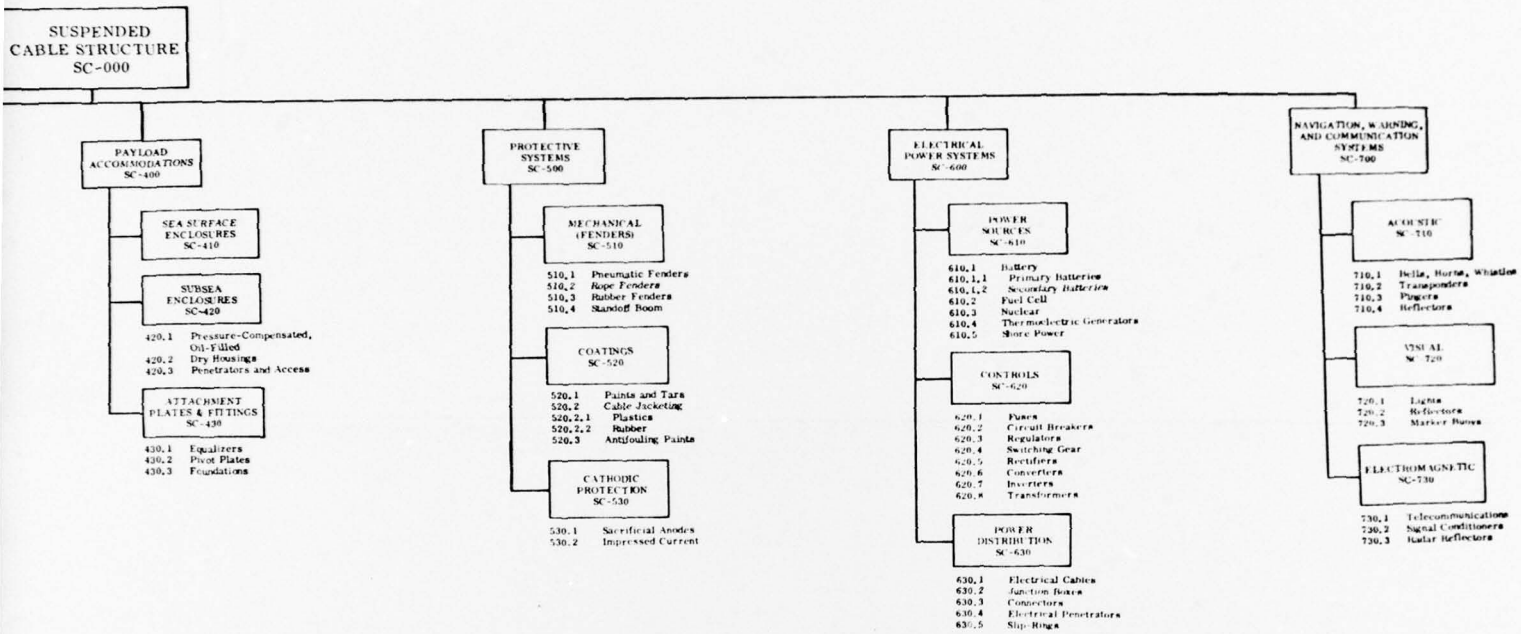
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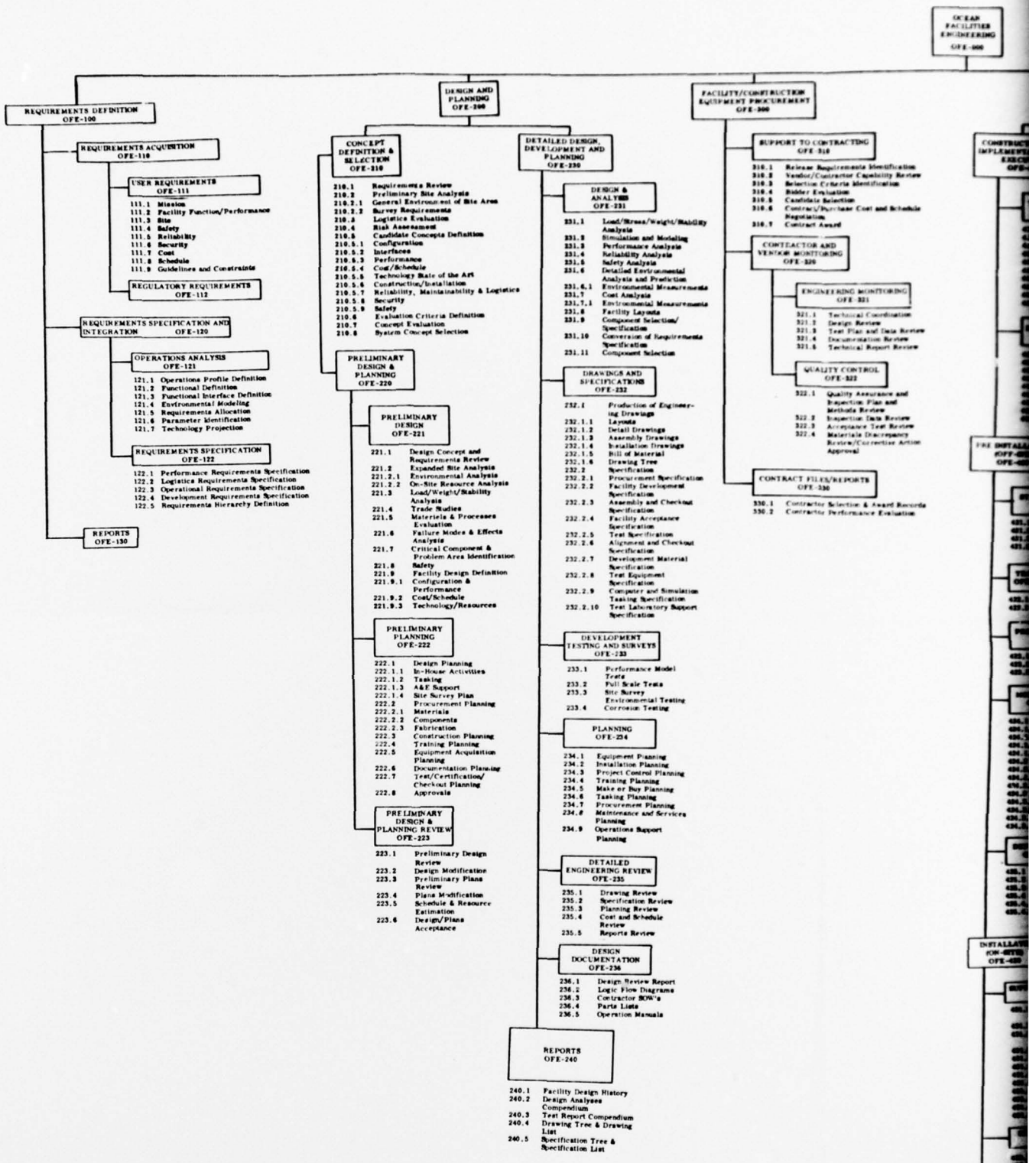
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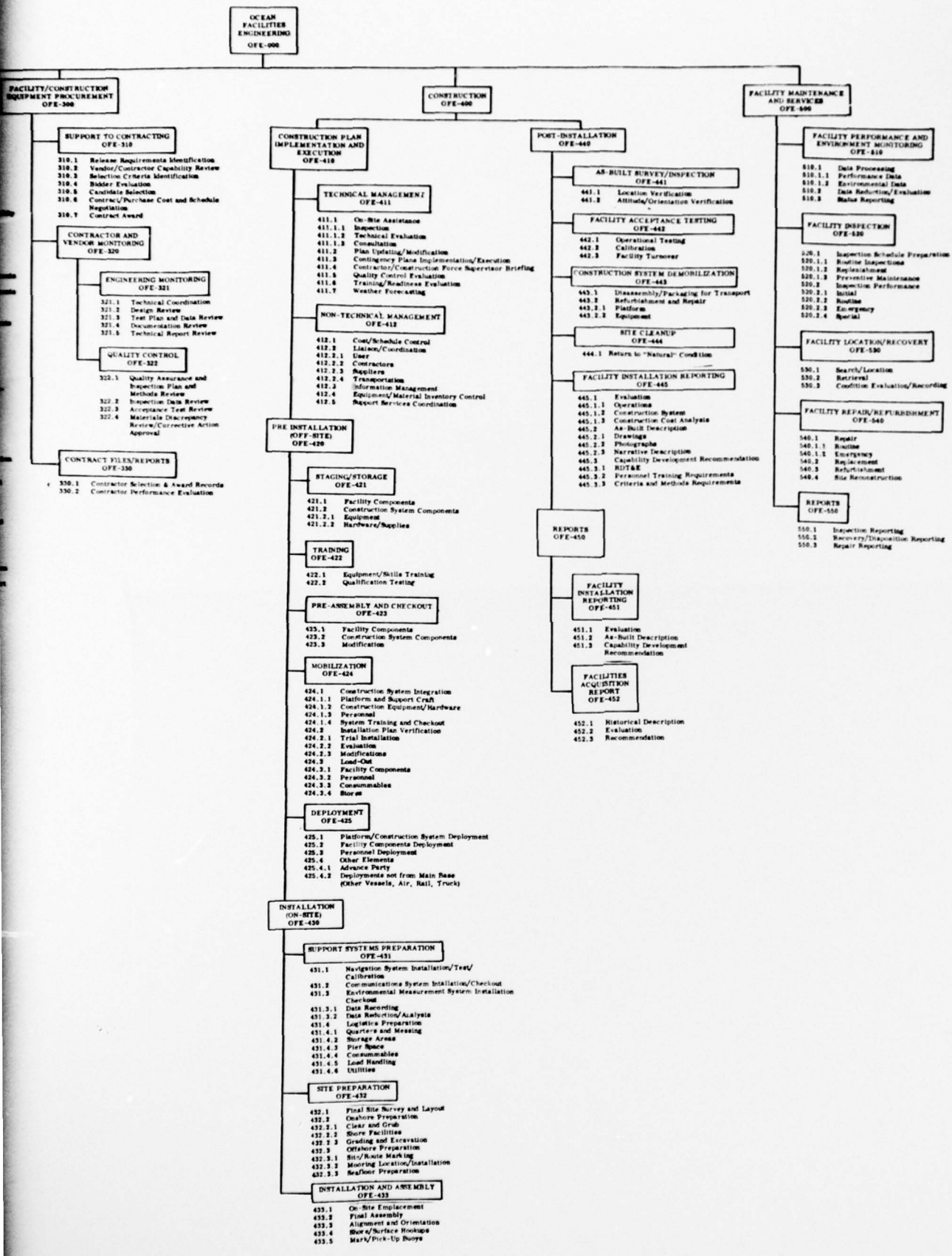
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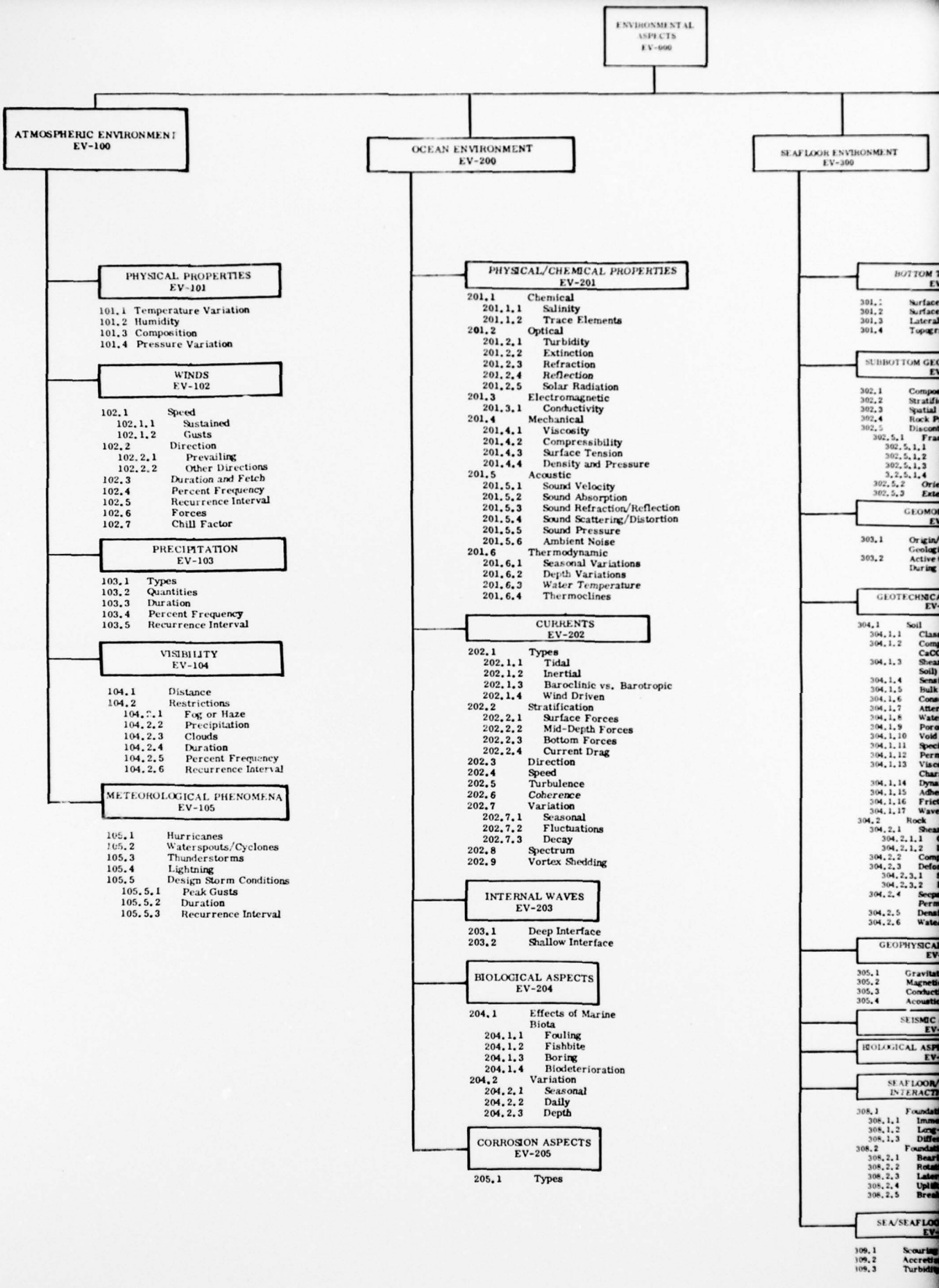
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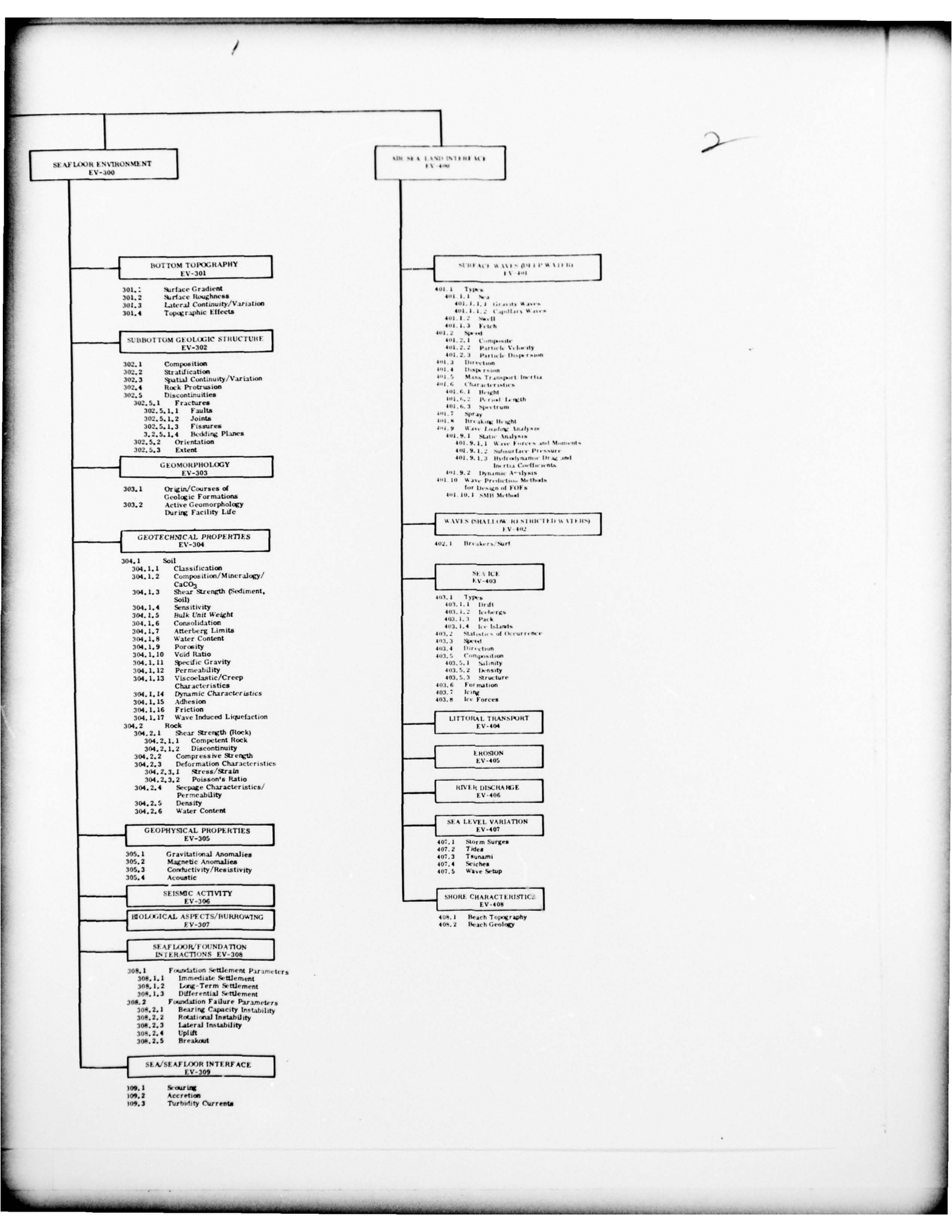
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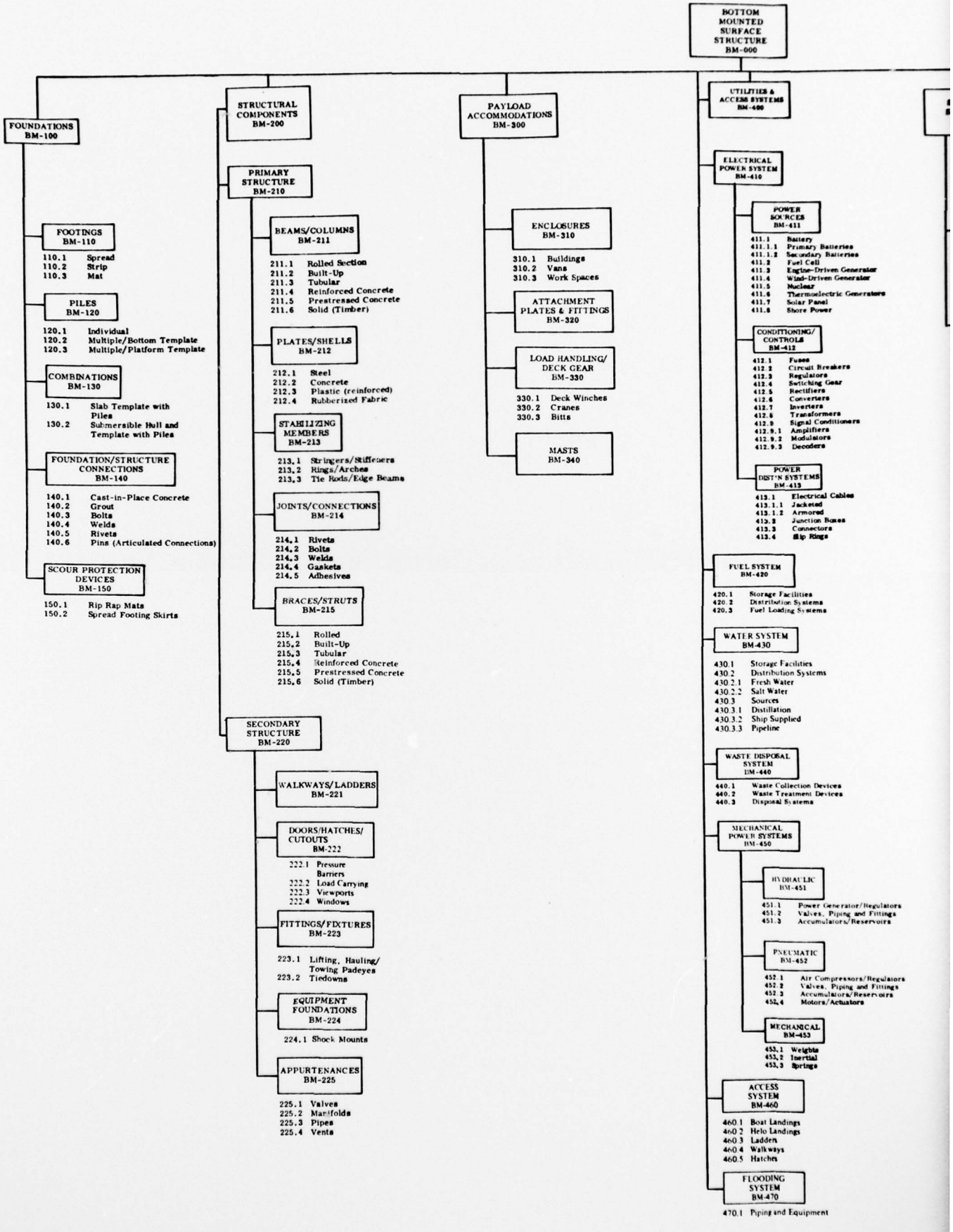
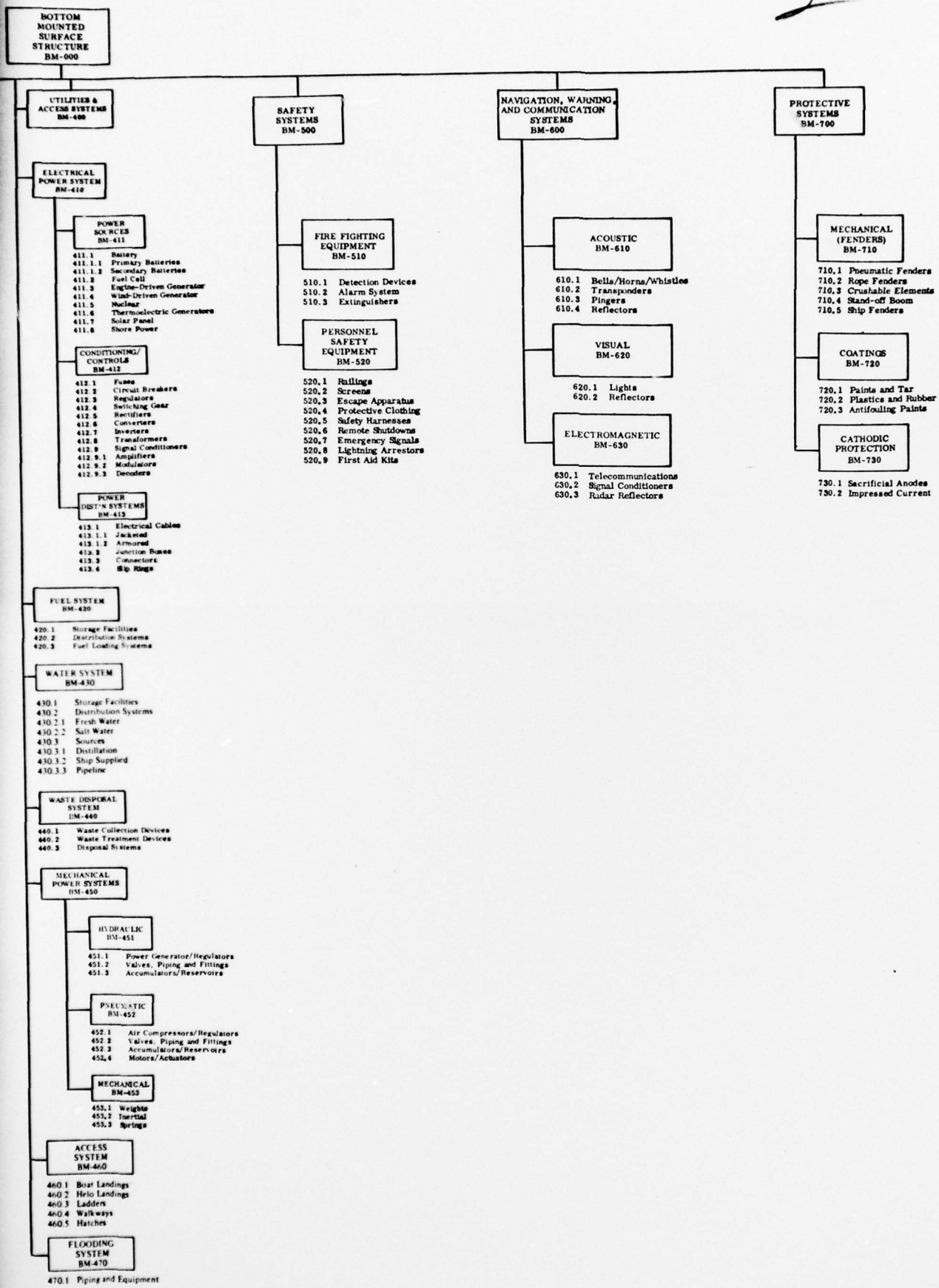

BOTTOM MOUNTED SURFACE STRUCTURE BM-000
FOUNDATIONS BM-100
FOOTINGS BM-110
110.1 Spread
110.2 Strip
110.3 Mat
PILES BM-120
120.1 Individual
120.2 Multiple/Bottom Template
120.3 Multiple/Platform Template
COMBINATIONS BM-130
130.1 Slab Template with Piles
130.2 Submersible Hull and Template with Piles
FOUNDATION/STRUCTURE CONNECTIONS BM-140
140.1 Cast-in-Place Concrete
140.2 Grout
140.3 Bolts
140.4 Welds
140.5 Rivets
140.6 Pins (Articulated Connections)
SCOUR PROTECTION DEVICES BM-150
150.1 Rip Rap Mats
150.2 Spread Footing Skirts
STRUCTURAL COMPONENTS BM-200
PRIMARY STRUCTURE BM-210
BEAMS/COLUMNS BM-211
211.1 Rolled Section
211.2 Built-Up
211.3 Tubular
211.4 Reinforced Concrete
211.5 Prestressed Concrete
211.6 Solid (Timber)
PLATES/SHELLS BM-212
212.1 Steel
212.2 Concrete
212.3 Plastic (reinforced)
212.4 Rubberized Fabric
STABILIZING MEMBERS BM-213
213.1 Stringers/Stiffeners
213.2 Rings/Arches
213.3 Tie Rods/Edge Beams
JOINTS/CONNECTIONS BM-214
214.1 Rivets
214.2 Bolts
214.3 Welds
214.4 Gaskets
214.5 Adhesives
BRACES/STRUTS BM-215
215.1 Rolled
215.2 Built-Up
215.3 Tubular
215.4 Reinforced Concrete
215.5 Prestressed Concrete
215.6 Solid (Timber)
SECONDARY STRUCTURE BM-220
WALKWAYS/LADDERS BM-221
DOORS/HATCHES/CUTOUTS BM-222
222.1 Pressure Barriers
222.2 Load Carrying
222.3 Viewports
222.4 Windows
FITTINGS/FIXTURES BM-223
223.1 Lifting, Hauling/Towing Padeyes
223.2 Tiedowns
EQUIPMENT FOUNDATIONS BM-224
224.1 Shock Mounts
APPURTENANCES BM-225
225.1 Valves
225.2 Manifolds
225.3 Pipes
225.4 Vents
PAYLOAD ACCOMMODATIONS BM-300
ENCLOSURES BM-310
310.1 Buildings
310.2 Vans
310.3 Work Spaces
ATTACHMENT PLATES & FITTINGS BM-320
LOAD HANDLING/DECK GEAR BM-330
330.1 Deck Winches
330.2 Cranes
330.3 Bitts
MASTS BM-340
UTILITIES & ACCESS SYSTEMS BM-400
ELECTRICAL POWER SYSTEM BM-410
POWER SOURCES BM-411
411.1 Battery
411.1.1 Primary Batteries
411.1.2 Secondary Batteries
411.2 Fuel Cell
411.3 Engine-Driven Generator
411.4 Wind-Driven Generator
411.5 Nuclear
411.6 Thermoelectric Generators
411.7 Solar Panel
411.8 Shore Power
CONDITIONING/CONTROLS BM-412
412.1 Fuses
412.2 Circuit Breakers
412.3 Regulators
412.4 Switching Gear
412.5 Rectifiers
412.6 Converters
412.7 Inverters
412.8 Transformers
412.9 Signal Conditioners
412.9.1 Amplifiers
412.9.2 Modulators
412.9.3 Decoders
POWER DIST'N SYSTEMS BM-413
413.1 Electrical Cables
413.1.1 Jacketed
413.1.2 Armored
413.2 Junction Boxes
413.3 Connectors
413.4 Slip Rings
FUEL SYSTEM BM-420
420.1 Storage Facilities
420.2 Distribution Systems
420.3 Fuel Loading Systems
WATER SYSTEM BM-430
430.1 Storage Facilities
430.2 Distribution Systems
430.2.1 Fresh Water
430.2.2 Salt Water
430.3 Sources
430.3.1 Distillation
430.3.2 Ship Supplied
430.3.3 Pipeline
WASTE DISPOSAL SYSTEM BM-440
440.1 Waste Collection Devices
440.2 Waste Treatment Devices
440.3 Disposal Systems
MECHANICAL POWER SYSTEMS BM-450
HYDRAULIC BM-451
451.1 Power Generator/Regulators
451.2 Valves, Piping and Fittings
451.3 Accumulators/Reservoirs
PNEUMATIC BM-452
452.1 Air Compressors/Regulators
452.2 Valves, Piping and Fittings
452.3 Accumulators/Reservoirs
452.4 Motors/Actuators
MECHANICAL BM-453
453.1 Weights
453.2 Inertial
453.3 Springs
ACCESS SYSTEM BM-460
460.1 Boat Landings
460.2 Helo Landings
460.3 Ladders
460.4 Walkways
460.5 Hatches
FLOODING SYSTEM BM-470
470.1 Piping and Equipment


BOTTOM MOUNTED SURFACE STRUCTURE BM-000
UTILITIES & ACCESS SYSTEMS BM-400
SAFETY SYSTEMS BM-500
NAVIGATION, WARNING, AND COMMUNICATION SYSTEMS BM-600
PROTECTIVE SYSTEMS BM-700
ELECTRICAL POWER SYSTEM BM-410
POWER SOURCES BM-411
411.1 Battery
411.1.1 Primary Batteries
411.1.2 Secondary Batteries
411.2 Fuel Cell
411.3 Engine-Driven Generator
411.4 Wind-Driven Generator
411.5 Nuclear
411.6 Thermoelectric Generators
411.7 Solar Panel
411.8 Shore Power
CONDITIONING/ CONTROLS BM-412
412.1 Fuses
412.2 Circuit Breakers
412.3 Regulators
412.4 Switching Gear
412.5 Rectifiers
412.6 Converters
412.7 Inverters
412.8 Transformers
412.9 Signal Conditioners
412.9.1 Amplifiers
412.9.2 Modulators
412.9.3 Decoders
POWER DIST'N SYSTEMS BM-413
413.1 Electrical Cables
413.1.1 Jacketed
413.1.2 Armored
413.2 Junction Boxes
413.3 Connectors
413.4 Slip Rings
FUEL SYSTEM BM-420
420.1 Storage Facilities
420.2 Distribution Systems
420.3 Fuel Loading Systems
WATER SYSTEM BM-430
430.1 Storage Facilities
430.2 Distribution Systems
430.2.1 Fresh Water
430.2.2 Salt Water
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430.3.1 Distillation
430.3.2 Ship Supplied
430.3.3 Pipeline
WASTE DISPOSAL SYSTEM BM-440
440.1 Waste Collection Devices
440.2 Waste Treatment Devices
440.3 Disposal Systems
MECHANICAL POWER SYSTEMS BM-450
HYDRAULIC BM-451
451.1 Power Generator/Regulators
451.2 Valves, Piping and Fittings
451.3 Accumulators/Reservoirs
PNEUMATIC BM-452
452.1 Air Compressors/Regulators
452.2 Valves, Piping and Fittings
452.3 Accumulators/Reservoirs
452.4 Motors/Actuators
MECHANICAL BM-453
453.1 Weights
453.2 Inertial
453.3 Springs
ACCESS SYSTEM BM-460
460.1 Boat Landings
460.2 Helo Landings
460.3 Ladders
460.4 Walkways
460.5 Hatches
FLOODING SYSTEM BM-470
470.1 Piping and Equipment
FIRE FIGHTING EQUIPMENT BM-510
510.1 Detection Devices
510.2 Alarm System
510.3 Extinguishers
PERSONNEL SAFETY EQUIPMENT BM-520
520.1 Railings
520.2 Screens
520.3 Escape Apparatus
520.4 Protective Clothing
520.5 Safety Harnesses
520.6 Remote Shutdowns
520.7 Emergency Signals
520.8 Lightning Arrestors
520.9 First Aid Kits
ACOUSTIC BM-610
610.1 Bells/Horns/Whistles
610.2 Transponders
610.3 Pingers
610.4 Reflectors
VISUAL BM-620
620.1 Lights
620.2 Reflectors
ELECTROMAGNETIC BM-630
630.1 Telecommunications
630.2 Signal Conditioners
630.3 Radar Reflectors
MECHANICAL (FENDERS) BM-710
710.1 Pneumatic Fenders
710.2 Rope Fenders
710.3 Crushable Elements
710.4 Stand-off Boom
710.5 Ship Fenders
COATINGS BM-720
720.1 Paints and Tar
720.2 Plastics and Rubber
720.3 Antifouling Paints
CATHODIC PROTECTION BM-730
730.1 Sacrificial Anodes
730.2 Impressed Current